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COMPILATION OF

MATERIALS RESEARCH DATA

A. F. Hooper

Fourth Quarterly Progress Report - Phase I
1 March 1963 to 27 May 1963

Contract AF33(616)-7984
Task No. 738103

27 May 1963

AR-592-1-415

27 March 1963

TO: Distribution

FROM: MATERIALS RESEARCH GROUP, 592-1

TITLE: The Effect of Cryogenic Temperatures on the Mechanical Properties of Reinforced Plastic Laminates

ABSTRACT: The tensile properties of four reinforced plastic laminates (Conolon 522, Conolon 527, Conolon 534 and Narmco 406-181) have been investigated and are tabulated. A survey has been made on all available information on the properties of reinforced plastic laminates at cryogenic temperatures, and the influence of resin system, cure cycle, resin content, etc. are discussed. The survey includes data on tensile, flexural and compressive properties, as well as some data on fatigue properties, shear strength, impact strength and notched tensile strength.

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DISCUSSION

The use of reinforced plastic laminates for large structural parts on both ATLAS and CENTAUR has resulted in the requirement for the mechanical properties of these laminates under exposure to extreme subzero temperatures. Since early in 1959, General Dynamics/Astronautics (GD/A) has investigated the properties of laminates at temperatures as low as -423° F. The letting of contracts to build various stages of the Saturn vehicle, has resulted in increased interest in the low temperature properties of reinforced plastics by other aerospace companies. Recently Narmco Research & Development, A Division of Telecomputing Corporation completed a program sponsored by WADD under Contract No. AF 33(616)-8289, entitled, "Determination of the Performance of Plastic Laminates Under Cryogenic Temperatures." Under this contract, they evaluated the tensile, compressive, flexural and fatigue properties of ten commonly used reinforced plastic laminates. They have been awarded a continuation to this program, and will be evaluating a number of additional materials, as well as evaluating the bearing properties of reinforced plastics at cryogenic temperatures. This report contains much of the data obtained by Narmco, as well as some data obtained by GD/A, Douglas, Martin, North American, Westinghouse, Lewis Research Laboratories, and Ohio State University (see Ref. 1-15).

Tables I through IV give the tensile properties obtained at GD/A on four reinforced plastics at 78°, -100°, -320°, and -423° F. The -423° F specimen temperature was obtained by immersion of the specimen in liquid hydrogen, the -320° F specimen temperature was obtained by immersion in liquid nitrogen and the -100° F specimen temperature was obtained by immersion in a solution of dry ice and denatured ethyl alcohol. Specimens were supplied by the Narmco Materials Division and were of the configuration shown in Reference 1. The specimens contained bonded doublers, and because of some difficulty encountered in previous testing (Ref. 1 and 2) they were also held together by a small screw through each corner of the doubler. Properties of the B-staged cloth used to make each of the laminates and the processing cycles for the manufacture of these laminates are given in Table V. With the exception of the Narmco 406-181, the laminates were made of twelve plies of B-staged 181 fiberglass cloth using a parallel lay-up. The Narmco 406-181 was made of alternate layers of 181 style "E" glass cloth and Metlbond 406 (epoxy-nylon adhesive). The specimens were machined so that the warp direction was the same as the direction of applied tension.

Conolon 534 is a prepreg made of phenyl-silane resin impregnated on "E" glass. Conolon 527 is a general purpose polyester on "E" glass, while Conolon 522 is a general purpose epoxy resin on "E" glass. In each case, the glass utilized was style 181. The glass finish was A-1100 with the Conolon 534 laminate, while a Volan A finish was used on the glass with both the epoxy and polyester laminates.

Tables VI, VII and VIII tabulate all the available data on the tensile, compressive and flexural properties of reinforced laminates. The tables are constructed so that the ultimate strength, initial modulus and secondary modulus is reported at room temperature and then followed by the ratios of -100°, -320° and -423° F values to those obtained at room temperature. These tables include all available information on the manufacturing of the specific laminates, final resin content and specific gravity. In almost all cases, the panels were nominally 1/8" thick.

Tensile specimens were tested per Federal Test Method Standard No. 406, Method 1011. As far as could be determined, the loading rate for most of the specimens was approximately .05 inches/minute of head travel. Therefore, the difference in properties normally associated with large differences in load or strain rates is not apparent in the data reported in Table VI. Since a majority of the data reported is on 1/8" thick laminates made with style 181 "E" glass, the effect of thickness on laminate strength will not be a contributing factor to the ultimate strengths reported. The specimens tested at North American were made on specimens containing 4 plies of style 116 cloth, and therefore, the values reported may be slightly lower than one would expect with 1/8" laminates. Testing at GD/A on vacuum bagged phenolics reinforced with style 181 fiberglass indicated that laminates made with 4 plies resulted in approximately 95% of the ultimate tensile strength and approximately 95% of the initial modulus of elasticity of that obtained with a 12 ply laminate. The laminates made with Selectron 5003 at Ohio State University were approximately 1/2" thick. Very little information is available on the effect of thick laminates on mechanical properties, but testing at Forest Products Laboratory indicates that the tensile strength would vary from approximately 95% to 110% of that obtained on 1/8" thick laminates.

Comparing the data on epoxy-fiberglass laminates in Table VI, the following trends show up: 1) increase in fabrication pressure results in higher strength and moduli, 2) strength increases approximately 50% at -100° F and 100% at both -320° and -423° F over test values obtained at room temperature, 3) initial modulus is approximately the same at -100° F as at room temperature, increases 24% at -320° F, but increases only 13% at -423° F, as compared to the room temperature modulus, and 4) secondary modulus at cryogenic temperatures is approximately 90% of the room temperature secondary modulus.

Phenolic-fiberglass laminates behave in a like manner to that of the epoxy-fiberglass laminates. The same trends which are apparent with the epoxies are observed with the phenolics; i.e., 1) strength and moduli increase with fabrication pressure, 2) ultimate tensile strength increases approximately 33% when going from room temperature to either -320° or -423° F, 3) average initial modulus of elasticity is approximately 10% higher at cryogenic temperatures than at room temperature, and 4) average secondary modulus of elasticity decreases about 10% at cryogenic temperatures as compared to the average room temperature modulus. There is insufficient data on cotton reinforced phenolics to draw any conclusions. The one fiberglass reinforced phenyl-silane laminate resulted in properties very close to the average values obtained on phenolic-fiberglass laminates.

Silicone-fiberglass composites followed the trends of previously discussed laminates. Generally, the tensile properties increased with increasing fabrication pressure; average ultimate tensile strength increased 72% at -100° F, 140% at -320° F and 181% at -423° F, as compared to the average room temperature tensile strength; average initial and secondary moduli were approximately the same at -100° and -320° F as that obtained at room temperature, but increased slightly at -423° F.

Polyester-fiberglass laminates behaved in the same manner as the previously discussed resin systems, with the increases in strength and moduli at cryogenic temperatures more closely approximating the phenolic-fiberglass systems than either the epoxy-fiberglass or silicone-fiberglass systems. Included in the averages for the polyester-fiberglass systems are two high temperature formulations, Vibrin 135 and Laminac 4232, which would chemically vary quite markedly from other polyesters. The averages would be only slightly affected had these two resin systems been segregated under a separate category.

Based on the trends which have appeared in all the resin systems evaluated, the following generalized conclusions can be drawn for the tensile properties of resin-impregnated fiberglass laminates at cryogenic temperatures:

(1) Increased curing pressure results in higher strength and moduli values.

(2) Decrease in test temperature down to -320° F will result in marked increase in ultimate strength.

(3) Strength values at -320° F and at -423° F are approximately the same.

(4) There is very little change in moduli values over the temperature range of -423° to 75° F.

If one considers the resin-impregnated fiberglass laminate as a structural material (fiberglass) embedded in a cushioning material (resin), than one can immediately see why Conclusion #1 is valid. Since by increasing the curing pressure there is more glass per unit of cross-sectional area, the tensile properties would be expected to increase with increase in pressure. Thus, if a 12 ply laminate was .110" thick, instead of .125 inch thick, the failure load might be the same, but the ultimate strength per cross-sectional area would be higher for the thinner laminates. The assumption that the resin acts to distribute the load and adds very little to the structural properties of the overall laminate is quite valid when one considers the large difference which exists between the structural properties of glass and resin. The difference is approximately twenty-to-one for most common "E" glass-resin systems. If curing pressure is increased to the point where insufficient resin remains to adequately cushion the glass and distribute the load, then the resulting structural properties will start to decrease.

Work at the National Bureau of Standards (Ref. 17) has shown that the ultimate tensile strength of glass will increase approximately 40-100% when going from room temperature to -320° F and will remain essentially the same from -320° to -423° F. Their work has shown that the tensile modulus of glass at cryogenic temperatures was about 10% higher than the room temperature value. This correlates well with the increased tensile properties of fiberglass reinforced laminates.

Recent work at M.I.T. and University of Vermont (Ref. 18-21) show that in a resin impregnated fiberglass system the resin is under tensile stress. Analytical work in this area has been conducted by the Naval Research Laboratories (Ref. 22). This tensile stress is a result of a combination of thermal stress (difference in thermal contraction rates between resin and glass from cure temperature to test temperature) and chemical shrinkage. The chemical shrinkage being a very small contributor to the overall tensile stress. As the test temperature decreases, the tensile stress increases. However, the strength of the resin also increases with decreased temperature. Should the rate of increased stress be such that it exceeds the resin strength, cracking of the resin will occur. Cracking of the resin could result in poorer distribution of load or abrasion of the glass. This may be the reason why some resin impregnated fiberglass laminates increase in strength to a greater degree than others. Resin content may also play a role in this area, since GD/A has observed that many resin castings will crack when suddenly exposed to cryogenic temperatures. This is probably a result of the good insulating properties of the resin, combined with the high thermal contraction rates of the material. Since the surface sees the temperature while the interior of the casting is still warm, large thermal stresses are set up. One would expect that higher resin contents would result in less efficient laminates at cryogenic temperatures; however, there is insufficient data available to show any trend in this area.

Table VII is a compilation of the effect of cryogenic temperatures on the edgewise compressive strength of reinforced plastic laminates. Some flatwise compression data has also been included. The same trends which were apparent with the tensile properties of reinforced laminates at cryogenic temperatures were also found when reviewing the compressive properties. The various methods utilized for the compression testing would tend to cause a larger scatter in results than might ordinarily be expected. The specimens utilized by Narmco were small blocks 3/8" x 3/8" x 3/4", and in some cases, the LH_2 testing was accomplished with 1/4" x 1/4" x 1/2" because the increase in strength at -423° F resulted in specimen strengths which exceeded the capacity of their test machine. The differences in specimen thickness will, in itself, result in some differences in ultimate strength. In most cases, the other experimenters utilized specimens per Federal Test Method Standard No. 406, Method 1021, or slight variations thereof. There is no way of estimating the effect of these differences in test specimen configuration on final test results. In general, the increase in compressive properties of epoxy and polyester systems, at cryogenic temperatures, was approximately the same as those observed in the tensile tests. The phenolic and silicone systems generally showed lower increases in compression tests than in tensile tests.

Some unusually high moduli values were observed by Narmco, and in some cases, the values were not used in obtaining the averages in Table VII. The modulus is a much more difficult property to obtain than the ultimate strength, and a slight amount of icing, eccentric loading or uneveness in specimen surface can influence the results drastically. It is felt, by this writer, that the tensile moduli results would be more reliable than the compressive moduli results because of the comparative ease in obtaining strain measurements in the tensile tests.

The data reported by North American on phenolic-fiberglass laminates loaded at 45° to the warp appears extremely low. A recent conversation with North American personnel has revealed that some of their latest tests with very wide specimens result in strength properties in the 45° direction which more closely approximate the values obtained in the warp direction.

Table VIII is a compilation of the effect of cryogenic temperatures on the flexural properties of reinforced plastic laminates. The tests were run per Federal Test Method Standard No. 406, Method 1031. The flexural properties are influenced considerably by span-to-thickness ratio, and in almost all cases, this information was not available. In general, the trends observed with tensile and compressive properties of laminates at cryogenic temperatures were also found to exist with the flexural properties of laminates. Room temperature properties were generally higher in flexure than in tension or compression, and the increase at cryogenic temperatures were generally smaller. The largest increases in properties were obtained with the epoxies. The silicone and phenolic systems showed the next largest increase with decrease in temperature, while the polyesters showed very little increase with decrease in test temperature. The results on thin phenolic-fiberglass laminates were extremely erratic and may be misleading. Since the flexure test does result in shear stresses being applied to the laminate, it would be expected to result in smaller increases in strength than either the pure tension or pure compression tests. Since resins are notoriously poor adhesives at cryogenic temperatures when tested in peel, there may be an early resin-to-glass bond failure in flexure tests which would result in poor distirbution of loads and would lead to early failure. Like the compression tests, most of the flexure strain data was taken by measuring the movement of the test fixture rather than the test specimen. This is not as reliable a method as measuring the strain of the specimen itself, and therefore, the flexural moduli reported are possibly less accurate than the tensile moduli.

Testing of specimens at -100° F tends to give less accurate information than testing at -320° or -423° F. Since the samples are immersed in a mixture of dry ice and denatured ethyl alcohol (Narmco used dry ice and isopropyl alcohol), it is difficult to keep the temperature constant throughout the length of the test and over the full length of the specimen. This problem does not exist when specimens are immersed in a constant temperature bath, such as liquid nitrogen or liquid hydrogen. The ice bath can also cause problems resulting from ice wedging into the test fixture. The effect of different alcohols on the strength of reinforced laminates is another area which must be investigated before the -100° F properties can be accepted without question. It

appears that the use of a cold box would be warranted, even though it is a slower method.

The values reported in Tables VI, VII and VIII for each of the individual resin systems are an average of at least four specimens and in some cases, as many as twelve specimens. Therefore, the averages for the generic groups (phenolic, epoxy, polyester, etc.) are often averages of thirty or more individual specimens. It is felt that such a large sampling would be a good basis for arriving at design allowables.

In addition to the tensile, compressive and flexural testing of laminates at cryogenic temperatures, other properties such as fatigue strength, impact strength, shear strength and notched tensile strengths have also been conducted by many of the aerospace companies and agencies. The fatigue strength of a polyester-fiberglass laminate was evaluated at -320° F at Ohio State University (Ref. 9). Both notched and unnotched specimens were evaluated, and it was found that the fatigue strengths were about 50% higher at -320° F than at 77° F throughout the range of 10^4 to 10^7 cycles.

Narmco R&D (Ref. 6) ran tensile fatigue tests on epoxy, phenolic, polyester and silicone laminates at room temperature, -110°, -320° and -423° F. The tensile fatigue performance of each material was based upon the average ultimate strength of the material at the test temperature. This allowed for a relative comparison of the fatigue resistance of a material at different cryogenic temperatures. In spite of the high increase in static strength at cryogenic temperatures, Narmco found that most of the laminates they tested performed equally well or better at cryogenic temperatures than their respective room temperature fatigue evaluation. It was found that the materials exceeded one million cycles at a percentage of the ultimate strength equal to or greater than the room temperature values. Narmco obtained the same shape S-n diagrams for the different temperatures with the two epoxy laminates (Epon 1001 and Epon 828) they evaluated. They found that the Epon 828 laminates resulted in a large spread of data when tested in fatigue. Narmco's fatigue tests on phenolic and polyester laminates resulted in curves having similar characteristics to those obtained with the epoxy laminates. These curves all tended to flatten at 10^5 to 10^6 cycles. Narmco had difficulty in obtaining consistent fatigue data with silicone laminates.

No data has been found on the flexural fatigue properties of plastic laminates. Since the flexural properties of laminates appear to increase a smaller amount at cryogenic temperatures than the tensile and compressive properties, it appears that some flexural fatigue data is required.

Various organizations have run qualitative tests on reinforced plastics at cryogenic temperatures to determine the toughness of these materials in extreme subzero environments. Two approaches have been taken; i.e., 1) ratio of notched-unnotched tensile data, and 2) impact tests. Douglas Aircraft Company (Ref. 13) ran a series of tensile tests on laminates made of style 181 fiberglass impregnated with an Epon 828-CL hardener resin system. They ran typical LP-406b specimens - some of which contained a hole approximately 1/8"

in diameter - through the center of the specimen's minimum cross-section. Curves of tensile strength versus temperature were plotted for both the notched and unnotched specimens and resulted in almost parallel curves. Calculations of notched-unnotched ratios, using their data, result in the following values: 0.72, 0.87, 0.88 and 0.82 at room temperature, -65°, -320° and -423° F, respectively. Notched and unnotched tensile coupons of laminated glass filament reinforced plastics run at Lewis Research Laboratories resulted in a notched-to-unnotched tensile ratio at room temperature of approximately 0.90. This increased at -320° and -423° F so that the notched-to-unnotched ratio was approximately 0.94. The notched specimens used at Lewis were V-notched.

Charpy impact tests have been run by Westinghouse Electric Corporation and by Metal Control Laboratories for Westinghouse, with varying results. "V" notch Charpy impact tests on Micarta H2497 were run in both longitudinal and transverse directions at room temperature and at -320° F. Micarta H2497 is a high temperature epoxy-fiberglass laminate which meets MIL-P-18177, Grade GEB. At room temperature, impact strengths of 6.5 and 15.0 ft-lbs were obtained in the longitudinal and transverse directions, respectively. At -320° F, the average values were 8.0 and 27.8 ft-lbs, respectively. Testing of Micarta 262 (cotton-fabric-base reinforced phenolic meets MIL-P-15035, Grade FBM) resulted in Charpy values of 11.90 and 7.20 ft-lbs/inch width at room temperature for lengthwise and crosswise specimens, respectively. At -320° F, the values were 5.04 and 4.42 ft-lbs/inch, respectively.

Based on the small amount of testing to date, it appears that fiberglass reinforced plastic laminates retain their toughness at cryogenic temperatures; however, additional information is required in this area.

The only information available at this time on the interlaminar shear strength of plastic laminates at cryogenic temperatures is that testing performed at North American Aviation. They tested laminates which were made of style 116 "E" glass cloth, Volan A finish, impregnated with Monsanto SC-1008 phenolic resin. The laminates were 0.08 inches thick and were tested per Federal Standard No. 406, Method 1042. The specimens were loaded parallel to the warp and resulted in an average strength of 3270 psi at -300° F. This is approximately 30% higher than the room temperature interlaminar shear strength.

CONCLUSIONS

1. The tensile, compressive and flexural strengths of fiberglass reinforced plastic laminates increase approximately 30 to 120% when going from room temperature to -320° F.

2. The tensile, compressive and flexural strengths of fiberglass reinforced plastic laminates are approximately the same at -320° and -423° F.

3. The tensile, compressive and flexural moduli of fiberglass

reinforced plastic laminates increase only a small amount over the temperature range of -423° F to 78° F.

4. Fatigue strengths of fiberglass reinforced plastic laminates are higher at cryogenic temperatures than at room temperature.

5. Toughness of fiberglass reinforced plastic laminates at cryogenic temperatures, as measured by notched-to-unnotched tensile tests and impact tests, compares favorably with room temperature evaluations.

RECOMMENDATIONS

1. Flexural fatigue tests on fiberglass reinforced plastic laminates should be run at cryogenic temperatures.

2. Bearing tests should be run at cryogenic temperatures on fiberglass reinforced plastic laminates.

3. Additional impact testing of fiberglass reinforced plastic laminates at cryogenic temperatures is required.

4. Additional interlaminar shear tests of fiberglass reinforced plastic laminates is required.

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TABLE I

Tensile Properties of Conolon 534

Specimen Number	Temperature	Ultimate Tensile Strength psi	Initial Modulus psi x 10^6	Initial Proportional Limit psi	Secondary Modulus psi x 10^6
1	78° F	42,880	4.31	16,290	2.79
2		44,300	4.09	16,020	2.39
3		41,840	3.86	17,810	2.77
4		41,360	3.73	17,230	2.93
5		45,440	3.90	17,560	2.87
	Average	43,160	3.98	16,980	2.75
6	-100° F	62,380	4.14	11,570	2.49
7		60,630	4.47	8,280	2.20
8		59,850	3.74	9,200	2.14
9		60,290	4.17	7,800	2.38
10		63,620	3.80	11,610	2.32
	Average	61,350	4.06	9,690	2.31
11	-320° F	65,550	4.66	13,780	2.76
12		64,290	5.13	14,540	3.12
13		64,560	5.67	14,250	3.18
14		67,350	5.09	12,430	3.07
15		65,250	4.04	14,080	3.05
	Average	65,400	4.92	13,820	3.04
16	-423° F	69,610	-	-	-
17		72,730	5.12	17,240	2.66
18		68,240	4.92	18,380	2.74
19		67,720	6.27	17,750	2.69
20		68,280	4.17	17,600	2.80
	Average	69,320	5.12	17,740	2.72

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TABLE II

Tensile Properties of Conolon 527

Specimen Number	Temperature	Ultimate Tensile Strength psi	Initial Modulus psi x 10^6	Initial Proportional Limit psi	Secondary Modulus psi x 10^6
1	78° F	43,540	3.88	2,830	2.57
2		46,700	4.07	4,230	2.57
3		44,840	3.43	3,960	2.56
4		44,310	4.02	3,550	2.47
5		45,380	3.65	4,100	2.42
	Average	44,880	3.81	3,720	2.52
6	-100° F	66,460	-	7,230	1.69
7		65,300	3.63	7,060	1.96
8		65,750	-	-	1.88
9		63,020	2.68	7,640	1.84
10		62,940	3.20	6,210	1.95
	Average	64,690	3.17	7,040	1.86
11	-320° F	81,940	3.39	7,090	2.53
12		82,260	3.49	6,300	2.76
13		79,530	4.21	5,050	3.41
14		73,920	3.25	6,110	2.66
15		72,260	3.87	5,180	3.02
	Average	77,980	3.64	5,950	2.88
16	-423° F	64,200	3.12	6,590	2.72
17		75,050	2.97	-	2.69
18		65,780	2.91	10,340	2.60
19		74,390	3.58	13,150	2.80
20		66,890	3.06	12,050	2.73
	Average	69,260	3.13	10,530	2.71

TABLE III

Tensile Properties of Conolon 522

Specimen Number	Temperature	Ultimate Tensile Strength psi	Initial Modulus psi x 10^6	Initial Proportional Limit psi	Secondary Modulus psi x 10^6
1	78° F	40,470*	3.98	6,210	3.21
2		40,510	3.28	5,510	2.58
3		42,970*	3.80	3,550	2.91
4		48,460*	4.38	5,000	3.23
5		41,200*	4.10	4,860	3.11
	Average	42,720	3.91	5,030	3.01
6	-100° F	62,340	2.83	16,490	2.33
7		76,740	3.09	16,440	2.90
8		66,080	3.36	11,860	2.67
9		63,540	2.68	9,880	2.33
10		77,050	-	-	2.38
	Average	69,150	2.99	13,670	2.52
11	-320° F	105,170	4.33	31,300	2.78
12		94,820	6.34	33,870	2.99
13		78,330	3.98	41,310	1.95
14		107,940	4.60	34,180	2.74
15		83,080	3.93	22,720	1.91
	Average	93,870	4.64	32,680	2.47
16	-423° F	104,680	4.38	35,420	2.41
17		89,280	4.19	40,880	2.22
18		101,180	4.27	41,990	1.79
19		81,070	3.83	36,630	1.77
	Average	93,300	4.17	38,730	2.05

* Broke in doublers and pulled a second time.

TABLE IV

Tensile Properties of Narmco 406-181

Specimen Number	Temperature	Ultimate Tensile Strength psi	Initial Modulus psi x 10^6	Initial Proportional Limit psi	Secondary Modulus psi x 10^6
1	78° F	23,180	-	-	1.48
2		25,800	2.10	1,880	1.59
3		22,030	1.96	2,090	1.61
4		25,830	1.60	1,430	1.45
	Average	24,210	1.89	1,800	1.53
5	-100° F	45,720	1.84	12,970	1.34
6		44,210	1.80	12,820	1.40
7		45,820	2.00	7,740	1.67
8		44,710	1.34	11,670	1.23
9		36,700	-	-	1.17
	Average	43,430	1.75	11,300	1.36
10	-320° F	39,060	2.72	20,580	1.14
11		43,240	2.58	22,480	1.16
12		40,670	2.05	14,260	.94
13		45,970	2.72	20,900	.70
	Average	42,240	2.52	19,560	.99
14	-423° F	45,820	2.46	-	-
15		29,230	1.64	-	-
16		50,730	2.45	-	-
	Average	41,930	2.18	-	-

TABLE V

Fabrication of Cryogenic Structural Plastic Test Laminates

I. **MATERIALS**

	Material	Solids	% Volatiles	% Flow
(1)	Conolon 534-181 Alloo Cloth	38	4	15
(2)	Conolon 522-181 Volan A Cloth	38	2	20
(3)	Conolon 527-181 Volan A Cloth	42	3	18
(4)	Narmco 406-181 Volan A Cloth	38	1	20

II. **FABRICATION**

2.1 All panels were laid up in the warp direction.

2.2 All panels were encased in Mylar envelopes and placed between 1/4" cauls.

III. **CURE**

	Material	Pressure (psi)	Time (min.)	Temperature (°F)
(1)	534-181	Contact	7	250 preheated
		200	60	250
			24 hrs(postcure)	250
			24 hrs(postcure)	300
			24 hrs(postcure)	350
			8 hrs(postucre)	400
			48 hrs(postcure)	500
(2)	522-181	Contact	2-1/2	350 preheated
		20	60	350
(3)	527-181	-	-	275 preheated
		40	30	275
(4)	406-181	40	60	325

TABLE VI

Effect of Cryogenic Temperatures on Tensile Properties of [redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average Roo [redacted] Tensile Properties: Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6
Epoxies							
Conolon 522	GD/A	32.0	1.91	Cure: 2-1/2 min. contact at 350° F 1 hr. at 20 psi at 350° F 12 plies B-staged 181-Volan A Resin content 38%, Volatiles 2%, Flow 20%	42,700	3.91	3.01
Adlock EG-11A-81A	GD/A	36.8	1.45	Cure: Vacuum bagged 12-14 psi 1/2 hr. at 340° F Postcure: 1/2 hr. at 300° F 1/2 hr. at 400° F 12 plies B-staged 181-Volan A Resin content 41.0%, Volatiles 4.7%, Flow 17.6%	32,500	2.50	2.11
Epon 828	Narmco	36.2	1.83	Cure: 2 min. contact 1/2 hr. at 200 psi at 300° F Postcure: 1-1/2 hr. at 392° F Resin Content 41.0%, Volatiles 4.74%, Flow 17.6%	40,900	3.51	2.48
Epon 1001	Narmco	37.3	1.81	Cure: 1 min. contact 1/2 hr. at 200 psi at 330° F	49,000	3.34	2.61
Coast F-150-14	Martin	30 ± 2	-	Cure: 1/2 hr. at 250 psi at 350° F	60,700	2.9	-
Epon 828	Douglas	32 ± 4	-	Cure: 3 hrs. at 180° F, pressed to 1/8" stops Postcure: 2 hrs. at 350° F 1 hr. at 400° F 14 plies of 181-Volan A - wet lay-up with CL hardener	50,200	2.9 (1)	-
				AVERAGE (3)	46,000	3.23	2.55

(1) Secant modulus of elasticity at 70% of ultimate.

(2) Ratio of -65° F/R.T. tests.

(3) Average does not include modulus value of Epon 828.

TABLE VI

Temperatures on Tensile Properties of Reinforced Plastic Laminates

le and Remarks	Average Room Temp Tensile Properties			Ratio -100° to -110° F/R.T. Tensile Properties			Ratio -320°/R.T. Tensile Properties			Ratio -423°/R.T. Tensile Properties		
	Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.
tact at 350° F i at 350° F -Volan A latiles 2%, Flow 20%	42,700	3.91	3.01	1.62	.76	.84	2.20	1.19	.82	2.19	1.07	.68
12-14 psi ° F 300° F 400° F -Volan A Volatiles 4.7%, Flow 17.6%	32,500	2.50	2.11	1.26	.98	.91	1.80	1.18	.93	1.57	.89	.82
psi at 300° F it 392° F Volatiles 4.74%, Flow 17.6%	40,900	3.51	2.48	1.52	1.09	1.03	2.24	1.18	1.00	2.39	1.29	1.06
psi at 330° F	49,000	3.34	2.61	1.46	1.09	.97	1.94	1.18	1.00	2.06	1.28	.97
psi at 350° F	60,700	2.9	-	-	-	-	1.77	1.48	-	-	-	-
F, pressed to 1/8" stops 50° F 0° F A - wet lay-up with	50,200	2.9[1]	-	1.07[2]	1.10[1,2]	-	1.75	1.00[1]	-	1.72	1.13[1]	-
AVERAGE[3]	46,000	3.23	2.55	1.47	.98	.94	1.95	1.24	.94	1.99	1.13	.88

TABLE VI (Cont'd)

Effect of Cryogenic Temperatures on Tensile Properties of [redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average [redacted] Tensile Properties: Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6	Te U
Phenolics								
Conolon 506	GD/A	29.1	1.62	Cure: Vacuum bagged at 29 in. hg. Raised to 200° F in 20 min. 1/2 hr. at 200° F 1/2 hr. at 250° F 1/2 hr. at 300° F 2 hr. at 350° F 12 plies of B-staged 181-Volan A cloth Resin content 34.9%, Volatiles 7.7%	44,400	3.47	2.55	
Conolon 506	Narmco	32.0	1.74	Cure: 1 hr. at 30 psi at 350° F	38,100	3.65	2.78	1
Adlock 851	GD/A	31.6	1.64	Cure: Vacuum bagged at 12-14 psi 1/2 hr. at 200° F 1/2 hr. at 250° F 1/2 hr. at 300° F 3-1/2 hrs. at 350° F 12 plies of B-staged 181-A-1100 Resin Content 41.5%, Volatiles 7.1%, Flow 26.8%	40,400	3.03	2.14	1
Trevarno F-92	GD/A	-	-	Unknown	30,900	-	-	1
Micarta 262	Westing-house	-	-	Cotton fabric reinforcement	13,400(L) 9,030(T)	- -	- -	
CTL-91-LD	Narmco	25.7	1.91	Unknown	51,700	3.85	2.64	1
Coast F-120-14	Martin	30 ± 1	-	Cure: 3 min. at 162.5 psi at 325° F 8 min. at 15 psi at 325° F Postcure: 8 hrs. at 200° F 8 hrs. at 250° F Raised to 350° F in 4 hrs. Turned oven off and cooled.	56,300	2.7	-	

(4) Some of the specimens pulled at cryogenic temperatures failed in grips.

Notes: (L) warp in direction of applied load
(T) warp perpendicular to direction of applied load.

TABLE VI (Cont'd)

mperatures on Tensile Properties of Reinforced Plastic Laminates

and Remarks	Average Room Temp. Tensile Properties Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6	Ratio -100° to -110° F/R.T. Tensile Properties Ult.	Init. Mod.	Sec. Mod.	Ratio -320°/R.T. Tensile Properties Ult.	Init. Mod.	Sec. Mod.	Ratio -423°/R.T. Tensile Properties Ult.	Init. Mod.	Sec. Mod.
29 in. hg.	44,400	3.47	2.55	-	-	-	1.46+ [4]	1.34	1.08	1.50+ [4]	1.03	1.01
in 20 min.												
F												
F												
F												
1-Volan A cloth												
latiles 7.7%												
at 350° F	38,100	3.65	2.78	1.53	1.06	.95	1.95	1.30	1.03	1.90	1.05	.83
12-14 psi	40,400	3.03	2.14	1.12	.99	.75	1.71	1.02	.78	1.88	.89	.79
F												
F												
F												
0° F												
1-A-1100												
latiles 7.1%, Flow 26.8%												
	30,900	-	-	1.41	-	-	1.70	-	-	-	-	-
ment	13,400(L)	-	-	-	-	-	1.25	-	-	-	-	-
	9,030(T)	-	-	-	-	-	1.23	-	-	-	-	-
	51,700	3.85	2.64	1.27	1.12	-	1.26	1.10	1.15	1.25	1.16	1.10
psi at 325° F	56,300	2.7	-	-	-	-	1.69	1.11	-	-	-	-
at 325° F												
0° F												
0° F												
0° F in 4 hrs.												
off and cooled.												

l in grips.

TABLE VI (Cont'd)

Effect of Cryogenic Temperatures on Tensile Properties of [redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average [redacted] Tensile Properties Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6
Phenolics. (Cont'd)							
Monsanto SC-1008 coated by Western Backing	North American	-	-	Cure: 1/2 hr. at 180° F 1/2 hr. at 200° F 2 hrs. at 240° F 1/2 hr. at 260° F 1 hr. at 300° F 4 plies of B-staged 116 cloth Vacuum bagged at 27 in. hg.	40,000	3.46	-
Monsanto[6] SC-1008 coated by Western Backing	North American	-	-	Cure: 1/2 hr. at 180° F 1/2 hr. at 200° F 2 hrs. at 240° F 1/2 hr. at 260° F 1 hr. at 300° F 4 plies of B-staged 116 cloth Vacuum bagged at 27 in. hg.	24,000	2.11	-
				AVERAGE[7]	43,100	3.36	2.53

5 Ratio -300 /R.T.

6 Load applied at a 45° angle to warp.

7 Average does not include data on Monsanto SC-1008 loaded at 45° to warp nor data on cotton fabric reinforced

TABLE VI (Cont'd)

emperatures on Tensile Properties of Reinforced Plastic Laminates

	Average Room Temp. Tensile Properties			Ratio -100° to -110° F/R.T. Tensile Properties			Ratio -320°/R.T. Tensile Properties			Ratio -423°/R.T. Tensile Properties		
s and Remarks	Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.
F F F F 5 cloth . hg.	40,000	3.46	-	-	-	-	1.91 (5)	1.13 (5)	-	-	-	-
F F F F 5 cloth . hg.	24,000	2.11	-	-	-	-	1.35 (5)	1.41 (5)	-	-	-	-
AVERAGE (7)	43,100	3.36	2.53	1.33	1.06	.85	1.63	1.17	.99	1.63	1.03	.93

45° to warp nor data on cotton fabric reinforced laminates.

TABLE VI (Cont'd)

Effect of Cryogenic Temperatures on Tensile Properties of Re[redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average Roc[redacted] Tensile Pro[redacted] Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6
Phenyl Silane							
Conolon 534	GD/A	25.3	1.83	Cure: 7 min. contact at 250° F 1 hr. at 250° F at 200 psi Postcure: 24 hrs. at 250° F 24 hrs. at 300° F 24 hrs. at 350° F 8 hrs. at 400° F 48 hrs. at 500° F Resin content 38%, Volatiles 4%, Flow 15%	43,200	3.98	2.75
Silicones							
Coast F-130-14	Martin	30 ± 1	-	Cure: 1/2 hr. at 350° F at 150 psi Postcure: 16 hrs. at 200° F 2 hrs. at 250° F 2 hrs. at 300° F 6 hrs. at 450° F	38,800	2.8	-
Coast F-130	Narmco	31 ± 1[8]	1.83	Cure: 1 hr. at 325° F at 50 psi Postcure: 16 hrs. at 200° F 2 hrs. at 250° F 2 hrs. at 300° F 2 hrs. at 350° F 2 hrs. at 400° F 6 hrs. at 480° F	25,700	2.52	2.34
Narmco 513	Narmco	35.6[8]	1.84	Cure: 2 min. contact at 350° F 1 hr. at 350° F at 30 psi Postcure: 4 hrs. at 200° F 1 hr. at 275° F 1 hr. at 350° F 1 hr. at 400° F 1 hr. at 450° F 4 hrs. at 500° F	29,600	2.73	2.53
				AVERAGE	31,400	2.68	2.44

8) Percent resin for the prepreg.

TABLE VI (Cont'd)

gmenic Temperatures on Tensile Properties of Reinforced Plastic Laminates

Cure Cycle and Remarks	Average Room Temp. Tensile Properties Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6	Ratio -100° to -110° F/R.T. Tensile Properties Ult.	Init. Mod.	Sec. Mod.	Ratio -320°/R.T. Tensile Properties Ult.	Init. Mod.	Sec. Mod.	Ratio -423°/R.T. Tensile Properties Ult.	Init. Mod.	Sec. Mod.
contact at 250° F it 250° F at 200 psi hrs. at 250° F hrs. at 300° F hrs. at 350° F hrs. at 400° F hrs. at 500° F 38%, Volatiles 4%, Flow 15%	43,200	3.98	2.75	1.42	1.02	.84	1.52	1.24	1.11	1.61	1.29	.99
at 350° F at 150 psi hrs. at 200° F hrs. at 250° F hrs. at 300° F hrs. at 450° F	38,800	2.8	-	-	-	-	1.98	1.00	-	-	-	-
it 325° F at 50 psi hrs. at 200° F hrs. at 250° F hrs. at 300° F hrs. at 350° F hrs. at 400° F hrs. at 480° F	25,700	2.52	2.34	1.82	1.06	1.08	2.64	1.02	1.02	2.90	1.33	1.17
contact at 350° F t 350° F at 30 psi rs. at 200° F r. at 275° F r. at 350° F r. at 400° F r. at 450° F rs. at 500° F	29,600	2.73	2.53	1.61	1.00	1.02	2.58	1.01	1.00	2.72	1.13	1.09
AVERAGE	31,400	2.68	2.44	1.72	1.03	1.05	2.40	1.01	1.01	2.81	1.23	1.13

TABLE VI (Cont'd)

Effect of Cryogenic Temperatures on Tensile Properties of Reinf[redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average Room Temp. Tensile Properties Ult. psi	Init. Mod. psi x 10	Sec. Mod. psi x 10	-] Tensi Ult.
Epoxy-Nylon								
Narmco 406-181	GD/A	54.2	1.47	Cure: 1 hr. at 325° F at 40 psi Resin content 38%, Volatiles 1%, Flow 20%	24,200	1.89	1.53	1.79
Polyesters								
Conolon 527	GD/A	33.9	1.91	Preheated to 275° F and cured for 1/2 hr. at 40 psi at 275° F 12 plies of B-staged 181-Volan A Resin content 42%, Volatiles 3%, Flow 18%	44,900	3.81	2.52	1.44
Adlock PG-LA	GD/A	36.9	1.84	Vacuum bagged at 12-14 psi 1/2 hr. at 280° F 12 plies of B-staged 181-Volan A Resin content 39.1%, Resin flow 14.1%, Volatiles 3.5%	46,100	3.24	2.37	1.33
Paraplex P43	Narmco	40.3	1.83	Pressed at 30 psi- 1 hr. at 250° F	47,900	2.45	2.16	1.22
Hetron 92	Narmco	53.0	1.92	Unknown	39,200	2.46	-	1.61
Vibrin 135	Narmco	34.4	1.93	Cured in press: 1/2 hr. at 230° F, no pressure given. Postcure: 2 hrs. at 250° F 1 hr. at 350° F 1 hr. at 400° F 1 hr. at 425° F 1 hr. at 460° F 1 hr. at 480° F 3 hrs. at 500° F	32,700	3.36	-	1.76
Laminac 4232	Narmco	38.8	2.01	Cure: 1 hr. at 25 psi at 192° F 1 hr. at 25 psi at 250° F Postcure: 1/2 hr. at 300° F 1 hr. at 350° F 6 hrs. at 400° F 3 hrs. at 500° F	41,000	3.08	2.62	1.48
U.S. Polymeric C	Martin	30 ± 2	-	Molded 20 min. at 275° F and 162.5 psi	57,000	2.9	-	-
Selectron 5003	Ohio State	37.0	1.80	56 plies of 181-114 wet lay-up using 16% Luperco ATC catalyst	41,800	3.2	-	-
				AVERAGE	43,800	2.75	2.42	1.47

TABLE VI (Cont'd)

aic Temperatures on Tensile Properties of Reinforced Plastic Laminates

Cycle and Remarks	Average Room Temp. Tensile Properties			Ratio -100° to -110° F/R.T. Tensile Properties			Ratio -320°/R.T. Tensile Properties			Ratio -423°/R.T. Tensile Properties		
	Ult. psi	Init. Mod. psi x 10	Sec. Mod. psi x 10	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.
25° F at 40 psi , Volatiles 1%, Flow 20%	24,200	1.89	1.53	1.79	.93	.89	1.74	1.33	.65	1.73	1.15	-
F and cured for 1/2 hr. F ged 181-Volan A , Volatiles 3%, Flow 18%	44,900	3.81	2.52	1.44	.83	.74	1.74	.96	1.14	1.5[illegible]	.82	1.08
12-14 psi 1/2 hr. at 280° F ged 181-Volan A 1%, Resin flow 14.1%,	46,100	3.24	2.37	1.33	1.05	1.11	1.60	1.25	1.06	1.84	1.13	1.09
- 1 hr. at 250° F	47,900	2.45	2.16	1.22	1.35	1.02	1.70	-	1.19	1.63	1.30	1.08
	39,200	2.46	-	1.61	1.42	-	1.83	-	-	2.17	-	-
1/2 hr. at 230° F, no iven. at 250° F at 350° F at 400° F at 425° F at 460° F at 480° F at 500° F	32,700	3.36	-	1.76	1.04	-	1.59	1.11	-	1.67	1.12	-
psi at 192° F psi at 250° F at 300° F at 350° F at 400° F at 500° F	41,000	3.08	2.62	1.48	1.10	1.15	1.39	1.19	1.21	1.35	1.25	1.15
275° F and 162.5 psi	57,000	2.9	-	-	-	-	1.69	1.03	-	-	-	-
4 wet lay-up using talyst	41,800	3.2	-	-	-	-	1.67	1.16	-	-	-	-
AVERAGE	43,800	2.75	2.42	1.47	1.13	1.01	1.65	1.12	1.15	1.70	1.12	1.10

TABLE VII

Effect of Cryogenic Temperatures on Edgewise Compression Prope[redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average F[redacted] Edgewise Comp. Propertie Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6
Epoxies							
Epon 828	Narmco	36.2	1.83	See Table V	43,500	3.35	-
Epon 1001	Narmco	37.3	1.81	See Table V	58,600	3.75	-
				AVERAGE	51,100	3.55	-
Phenolics							
Conolon 506	GD/A	-	-	Cure: 1/2 hr. at 200° F 1/2 hr. at 250° F 1/2 hr. at 300° F 2 hrs. at 350° F Vacuum bagged	39,200	3.60	-
Conolon 506	Narmco	32.0	1.74	See Table V	46,500	4.39	-
Micarta 262 (4)	Westinghouse	-	-	Cotton Fabric Reinforcement	21,700	-	-
CTL-91-LD	Narmco	25.7	1.91	See Table V	70,400	4.69	-
Monsanto SC-1008 coated by Western Backing	North American	-	-	See Table V .040" thick	37,500	3.73	-
Monsanto (1) SC-1008 coated by Western Backing	North American	-	-	See Table V .040" thick	22,600	2.61	-
				AVERAGE (2)	48,400	4.10	-

(1) Load applied at 45° to warp.

(2) Average does not include data on Monsanto SC-1008 loaded at 45° nor data on cotton fabric reinforced lami

(3) This value not included in average.

(4) This material had a room temperature flatwise compression of 40,600 psi and a 76,700 psi flatwise compres

TABLE VII

Temperatures on Edgewise Compression Properties of Reinforced Plastic Laminates

ure Cycle and Remarks	Average Room Temp. Edgewise Comp. Properties: Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6	Ratio -100° to -110°/R.T. Edgw. Comp. Prop.: Ult.	Init. Mod.	Sec. Mod.	Ratio -320°/R.T. Edgw. Comp. Prop.: Ult.	Init. Mod.	Sec. Mod.	Ratio -423°/R.T. Edgw. Comp. Prop.: Ult.	Init. Mod.	Sec. Mod.
. V	43,500	3.35	-	1.96	.99	-	2.53	1.21	-	2.50	1.27	-
V	58,600	3.75	-	1.47	.88	-	1.53	1.04	-	1.35	1.06	-
AVERAGE	51,100	3.55	-	1.72	.93	-	2.03	1.13	-	1.93	1.17	-
2 hr. at 200° F 2 hr. at 250° F 2 hr. at 300° F hrs. at 350° F cuum bagged	39,200	3.60	-	-	-	-	1.46	1.11	-	-	-	-
V	46,500	4.39	-	1.18	1.70 (3)	-	1.76	1.03	-	1.65	1.17	-
bric Reinforcement	21,700	-	-	-	-	-	1.76	-	-	-	-	-
V	70,400	4.69	-	1.25	.77	-	1.41	1.80 (3)	-	1.30	.96	-
V ck	37,500	3.73	-	-	-	-	1.47	1.19	-	-	-	-
V ck	22,600	2.61	-	-	-	-	2.04	1.31	-	-	-	-
AVERAGE (2)	48,400	4.10	-	1.22	.77	-	1.53	1.11	-	1.48	1.07	-

aded at 45° nor data on cotton fabric reinforced laminate.

ssion of 40,600 psi and a 76,700 psi flatwise compression at -320° F (ratio = 1.89).

TABLE VII (Cont'd)

Effect of Cryogenic Temperatures on Edgewise Compression Properties o[redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average Room Temp. Edgewise Comp. Properties Ult. psi	Init. Mod. psi x 10	Sec. Mod. psi x 10	Ed Ult
Polyesters								
Hetron 92	Narmco	53.0	1.92	See Table V	22,900	1.57	-	1.5
Paraplex P43	Narmco	40.3	1.83	See Table V	31,500	2.75	-	1.3
Selectron 5003	Ohio State	37.0	1.80	See Table V	42,500	3.6	-	-
Laminac 4232	Narmco	38.8	2.01	See Table V	28,400	3.14	-	1.4
Vibrin 135	Narmco	34.4	1.93	See Table V	26,300	1.79	-	1.2
				AVERAGE	30,300	2.57	-	1.4
Silicones								
Narmco 513	Narmco	35.6 (5)	1.84	See Table V	25,300	2.72	-	1.1
Coast F-130	Narmco	31 ± 1 (5)	1.83	See Table V	17,700	2.06	-	1.3
				AVERAGE	21,500	2.39	-	1.2

(5) Percent resin for the prepreg.

TABLE VII (Cont'd)

mperatures on Edgewise Compression Properties of Reinforced Plastic Laminates

	Average Room Temp. Edgewise Comp. Properties			Ratio -100° to -110°/R.T. Edgw. Comp. Prop.			Ratio -320°/R.T. Edgw. Comp. Prop.			Ratio -423°/R.T. Edgw. Comp. Prop.		
ure Cycle and Remarks	Ult. psi	Init. Mod. psi x 10	Sec. Mod. psi x 10	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.
V	22,900	1.57	-	1.56	1.05	-	1.90	1.58	-	1.80	1.45	-
V	31,500	2.75	-	1.37	1.16	-	1.63	1.37	-	1.52	1.15	-
V	42,500	3.6	-	-	-	-	1.14	1.11	-	-	-	-
V	28,400	3.14	-	1.48	.88	-	1.68	.98	-	1.55	1.04	-
V	26,300	1.79	-	1.27	1.11	-	1.45	1.37	-	1.37	1.42	-
AVERAGE	30,300	2.57	-	1.42	1.05	-	1.56	1.28	-	1.56	1.27	-
V	25,300	2.72	-	1.13	.92	-	1.55	1.69	-	1.71	1.21	-
V	17,700	2.06	-	1.33	1.04	-	1.97	1.17	-	1.74	1.18	-
AVERAGE	21,500	2.39	-	1.23	.98	-	1.76	1.43	-	1.73	1.20	-

TABLE VIII

Effect of Cryogenic Temperatures on Flexural Properties of R[redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average Room [redacted] Flexural Prop[redacted] Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6
Epoxies							
Epon 828	Narmco	36.2	1.83	See Table V	77,900	3.54	-
Epon 1001	Narmco	37.3	1.81	See Table V	83,200	4.22	-
				AVERAGE	80,600	3.88	-
Phenolics							
Micarta 262	Westing-house	-	-	Cotton Fabric Reinforcement	21,200 18,400	1.36 1.06	- -
Conolon 506	Narmco	32.0	1.74	See Table V	63,400	3.56	-
Trevarno F-92	GD/A	-	-	Unknown	18,900	1.50	-
CTL-91-LD	Narmco	25.7	1.91	See Table V	77,400	4.32	-
Conolon 506	GD/A	-	-	Cure: 1/2 hr. at 200° F 1/2 hr. at 250° F 1/2 hr. at 300° F 2 hrs. at 350° F Vacuum bagged	61,600(L) 2 48,700(T) 2 50,800(L) 3 51,700(T) 3 60,300(L) 4 30,500(T) 4	2.93 2.77 3.01 2.46 1.36 1.21	- - - - - -
				AVERAGE 5,6	62,700	3.04	-
Silicones							
Narmco 513	Narmco	35.6 1	1.84	See Table V	34,100	2.85	-
Coast F-130	Narmco	31 ± 1 1	1.83	See Table V	36,100	2.69	-
				AVERAGE	35,100	2.77	-

1. Resin content of prepreg.
2. Laminates were .094 inches thick
3. Laminates were .062 inches thick
4. Laminates were .0217 inches thick
5. Average of laminates where warp is parallel to specimen length - does not include cotton base material. Data manufacturing procedures and contradictory information on specimen configuration.
6. Average includes thin laminates and is therefore lower than might otherwise be expected.

TABLE VIII

nic Temperatures on Flexural Properties of Reinforced Plastic Laminates

re Cycle and Remarks	Average Room Temp. Flexural Properties Ult. psi	Init. Mod. psi x 10^6	Sec. Mod. psi x 10^6	Ratio -100° to 110°/R.T. Flexural Properties Ult.	Init. Mod.	Sec. Mod.	Ratio -320°/R.T. Flexural Properties Ult.	Init. Mod.	Sec. Mod.	Ratio -423°/R.T. Flexural Properties Ult.	Init. Mod.	Sec. Mod.
V	77,900	3.54	-	1.27	1.12	-	1.93	1.42	-	1.86	1.32	-
V	83,200	4.22	-	1.26	.90	-	1.85	-	-	1.47	.89	-
AVERAGE	80,600	3.88	-	1.27	1.01	-	1.89	1.42	-	1.67	1.11	-
ric Reinforcement	21,200	1.36	-	-	-	-	1.28	1.32	-	-	-	-
	18,400	1.06	-	-	-	-	1.07	1.04	-	-	-	-
V	63,400	3.56	-	1.20	1.01	-	1.33	-	-	1.31	1.14	-
	18,900	1.50	-	1.43	1.53	-	1.48	1.27	-	-	-	-
V	77,400	4.32	-	1.29	.89	-	1.41	-	-	1.42	1.20	-
hr. at 200° F	61,600(L) 2	2.93	-	-	-	-	1.40	1.21	-	-	-	-
hr. at 250° F	48,700(T) 2	2.77	-	-	-	-	1.55	1.61	-	-	-	-
hr. at 300° F	50,800(L) 3	3.01	-	-	-	-	1.52	1.40	-	1.64	1.35	-
rs. at 350° F	51,700(T) 3	2.46	-	-	-	-	1.39	1.25	-	1.33	1.45	-
ged	60,300(L) 4	1.36	-	-	-	-	1.56	2.65	-	1.51	2.10	-
	30,500(T) 4	1.21	-	-	-	-	1.35	1.00	-	1.27	.95	-
AVERAGE 5,6	62,700	3.04	-	1.25	.95	-	1.44	1.75	-	1.47	1.45	-
V	34,100	2.85	-	1.19	1.12	-	1.53	1.12	-	1.55	1.08	-
V	36,100	2.69	-	1.20	1.01	-	1.76	1.06	-	1.67	1.23	-
AVERAGE	35,100	2.77	-	1.20	1.07	-	1.65	1.09	-	1.61	1.16	-

NOTE: (L) Indicates warp is parallel to specimen length.
(T) Indicates warp is perpendicular to specimen length.

en length - does not include cotton base material. Data on Trevarno F-92 is not included because of unknown
a on specimen configuration.
r than might otherwise be expected.

TABLE VIII (Cont'd)

Effect of Cryogenic Temperatures on Flexural Properties of [redacted]

Material	Testing Agency	Average Resin Content %	Average Specific Gravity	Cure Cycle and Remarks	Average Roo[redacted] Flexural Pr[redacted]		
					Ult. psi	Init. Mod. psi x 10	Sec. Mod. psi x 10
Polyesters							
Hetron 92	Narmco	53.0	1.92	See Table V	71,400	3.48	-
Paraplex P43	Narmco	40.3	1.83	See Table V	68,800	3.17	-
Laminac 4232	Narmco	38.8	2.01	See Table V	63,300	3.29	-
Vibrin 135	Narmco	34.4	1.93	See Table V	52,000	3.58	-
				AVERAGE	63,900	3.38	-

TABLE VIII (Cont'd)

ic Temperatures on Flexural Properties of Reinforced Plastic Laminates

	Average Room Temp. Flexural Properties			Ratio -100° to 110°/R.T. Flexural Properties			Ratio -320°/R.T. Flexural Properties			Ratio -423°/R.T. Flexural Properties		
Cycle and Remarks	Ult. psi	Init. Mod. psi x 10	Sec. Mod. psi x 10	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.	Ult.	Init. Mod.	Sec. Mod.
	71,400	3.48	-	1.15	1.01	-	1.22	.87	-	1.15	.85	-
	68,800	3.17	-	1.15	1.19	-	1.22	1,07	-	1.23	.93	-
	63,300	3.29	-	1.18	1.16	-	1.11	1.33	-	1.03	1.31	-
	52,000	3.58	-	1.47	1.12	-	1.50	1.13	-	1.44	1.12	-
AVERAGE	63,900	3.38	-	1.24	1.12	-	1.26	1.10	-	1.21	1.05	-